American POTATO JOURNAL

Volume 27 *October, 1950* *Number 10*

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$2.00 per year, United States and Canada, $2.50 per year elsewhere.

Entered as second class matter at New Brunswick, N. J., March 14, 1942, under Act of March 3, 1879.

Accepted for mailing at special rate of postage provided for in section 412, Act of February 28, 1925, authorized on March 14, 1928.

SULFUR AND CERTAIN SOIL AMENDMENTS FOR POTATO SCAB CONTROL IN THE PEAT SOILS OF NORTHERN IOWA[1]

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(Accepted for publication May 10, 1950)

Common scab of potatoes (*Streptomyces scabies* [Thaxt.] Waksman and Henrici) is the most important disease of the crop in Iowa, particularly on the highly calcareous peat soils which comprise most of the scattered commercial potato acreage of the state. The use of soil amendments for potato scab control has not previously been investigated in Iowa. Furthermore, to the best of the authors' knowledge, the use of sulfur as a means of controlling scab on highly calcareous peat soils has not been reported elsewhere, although tests on peat soil have been made (27, 28).

[1] Journal Paper No. J-1791 of the Iowa Agricultural Experiment Station, Project 1138.

[2] Research Assistant Professor and formerly Research Professor of the Botany and Plant Pathology Section. The authors express their appreciation to Drs. C. E. Peterson, R. H. Larson, and Henry Darling for potato stocks used in certain tests and to the Texas Gulf Sulfur Company for a grant in aid and for supplying the sulfur used. The cooperation and advice of J. G. Darroch of the Statistical Laboratory in the statistical treatments are especially appreciated. The assistance of L. J. Hirt, Sam Kennedy, and C. T. McLaughlin for field plots is gratefully acknowledged. Photographs were prepared by John Staby.

Tests with sulfur and other soil amendments have been made chiefly on mineral soils. One of the earliest reports is that of Beckwith (3) in which a degree of scab control was obtained by rolling moistened seed pieces in sulfur before planting. As early as 1895, Pammel (37) reported the method to be ineffective in controlling scab in Iowa. Between 1890 and 1900 sulfur was rather thoroughly tested both as a soil treatment and as a seed piece treatment in a number of states. This literature is carefully reviewed by Sherbakoff (41) and Lutman and Cunningham (32). Scab has been observed in soils as acid as pH 4.3 (15), pH 5.0 (42), pH 4.5 on muck, and 4.1 on Antigo loam (27), pH 4.4 (5, 43), pH 4.2 (35), and pH 3.5 to 3.8 (36).

In general, scab has been reported to be less severe in more acid soils. In a field survey Gillespie and Hurst (20) considered pH 5.2 to be the critical level above which scab was severe. Dippenaar (15) reported a negligible amount of scab under field conditions in soils with pH values of 5.3 or less. The maximum rate of increase of the scab organism occurred in soils pH 5.9 and above. Cook and Nugent (13) observed a significantly greater amount of scab in plots pH 4.8 to 5.5 than in plots below pH 4.8. Scab was significantly more severe (12) in plots at pH 5.2 to 6.0 than from plots at pH 4.7 to 5.1.

In a field survey (5), when soils were classified on the basis of surface soil pH, least scab developed at pH 4.3 to 5.4, more from pH 7.5 to 8.5, and most from pH 5.4 to 7.4. Blodgett and Cowan (6) demonstrated in pot experiments that scab was reduced by relatively acid soil conditions, pH 5.6 to 4.7, and that scab was progressively less severe as the alkalinity of the soil was increased from neutrality to pH 9.0. In a field survey, Goss (21) observed a very evident and consistent decrease in both the amount and severity of scab as the pH values increased from pH 5.9 to 8.2. Smith (42) adjusted the reaction of field plots using sulfuric acid and hydrated lime. With the scabby tubers removed, the highest percentage of U. S. No. 1 grade potatoes came from the most acid and the most alkaline soils and the lowest percentage from soils with a reaction between pH 6.0 and 7.0, or sometimes as high as pH 7.8. Larson *et al* (27) were unable to show scab reduction in soils of pH 7.5 to 8.0 following heavy lime applications to Antigo silt loam. Additions of sulfur reduced soil pH levels and scab incidence. Duff and Welch (16) observed at Devlin, Ontario, that scab was decidedly reduced by sulfur applications but the soil reaction was relatively unchanged, ranging from pH 6.7 to 7.4. At Rosthern, Saskatchewan, and Guelph, Ontario, they obtained a degree of scab reduction with relatively no change in soil reaction where sulfur had been broadcast.

Muncie *et al* (36) obtained evidence that there was some adaptation of the scab organism to acid soil conditions.

Materials and Methods

All trials were replicated four times in a randomized block arrangement except where Latin squares were possible. Fertilizer, 0-9-27, was drilled at right angles to the direction of the rows at rates of either 500 or 800 pounds per acre. Unless otherwise indicated, the Cobbler variety was used throughout and seed tubers were not treated with disinfectants before planting.

Broadcast sulfur applications were made in the spring a short time before planting. Sulfur was distributed by hand on plots 30 by 50 feet after which the soil was thoroughly disked to a 4-inch depth. In plots where the influence of residual sulfur was determined, potatoes were planted in subsequent years without further additions of sulfur.

Furrow applications were made by scattering sulfur and other chemicals in measured amounts into an open furrow and working them into the soil in such a manner that the developing tubers grew in the zone of treated soil. It was necessary to exercise considerable care in order to mix the chemicals thoroughly with the soil.

A third method of application, which did not prove satisfactory for scab control, was that of applying sulfur through the fertilizer attachment of the planter.

For scab records 50 medium-sized tubers were selected at random in the row. These were placed in the following categories according to the severity of disease: 0, no scab; 1, less than 5 per cent of the surface scabbed; 2, between 6 and 25 per cent of the surface scabbed; and 3, above 26 per cent of the surface scabbed. The number of tubers in each scab category was multiplied by the number of the category and the products added. Indices were expressed as percentages after dividing the sum by the product of the total number of tubers and, three, the number of the highest scab category.

In these tests, tubers with less than 6 per cent of the surface scabbed would generally have made a satisfactory marketable grade.

The hydrogen-ion concentration of the soil was determined electrometrically using a composite sample consisting of four or five smaller samples taken at random from the plot at depths of less than four inches. These were suspended in enough water to make a fluid suspension and measurements made after the hydrogen-ion concentration had become stable. The reaction listed in the tables thus indicates the hydrogen-ion concentration of the soil in which the tubers developed rather than the reaction of the soil in which the entire root system was located.

Sulfur was obtained from various sources. In 1944 and 1947 "Owl" brand dusting sulfur, 325 mesh, and 93-95 per cent pure was used throughout. In 1948 "Super Soil" ground sulfur was used, 80 per cent of which was 65 mesh or smaller. In 1949 "Mule Brand" sulfur was used containing 99.5 per cent sulfur, 90 per cent of which passed through an 80 mesh screen.

Experimental Results

Broadcast Applications of Sulfur

Sulfur was broadcast on plots of highly calcareous peat soil at Crystal Lake over a nine-year period (Table 1). In 1941 and 1942 sulfur was compared with a number of commercial fertilizers and certain soil disinfectants. Of the group, it was the only material effecting a degree of scab control. In these two years the addition of sulfur increased total tuber yields between 40 and 50 bushels per acre.

In 1943, rates of 500 and 1000 pounds of sulfur reduced the soil reaction (Fig. 1) (Table 1) and scab index slightly, and made no discernible

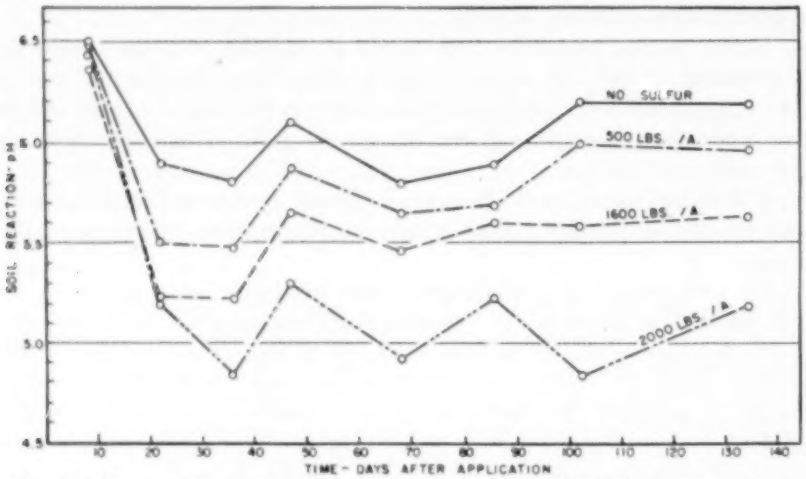

Fig. 1—Influence of broadcast sulfur on soil reaction at Crystal Lake, Iowa, 1943.

difference in tuber skin color. At the 2000-pound rate, the soil reaction was reduced from pH 6.4 to 4.9 in less than 40 days. In subsequent years, 2000 pounds of sulfur was not so effective in reducing the soil pH. Although there was some fluctuation in soil reaction throughout the season, the relative differences in hydrogen-ion concentration between treatments remained constant. Seasonal fluctuations in this order of magnitude have been reported previously (43). Total yields from the sulfur plots were significantly greater than the controls, whereas, differences in yields of tubers with less than 6 per cent of the surface scabbed were highly significant.

In 1944, the first planting was lost because of a flood, and a second planting was made early in July. It was possible to harvest the crop from only a portion of the area. As a result, combined data from four replications of both the untreated check plots and the 2000-pound rate are presented. The influence of 2000 pounds of sulfur per acre on soil reaction was somewhat less than in 1943. Although scab indices were only slightly reduced, yields of

TABLE 1—*Influence of sulfur on soil reaction, scab incidence, and yield of Cobbler potatoes on highly calcareous peat soil at Crystal Lake, Iowa.*

Year of Test	Sulfur[1]	Soil Reaction Range	Scab Index	Tuber Skin Appearance	Scab-Free Tubers		Tubers with Less Than 6 Per Cent Surface Scabbed			Total Yield[3]	
	Lbs. Acre	pH[2]	Per cent		Per cent	Bus. Acre	Per cent	Bus. Acre		Bus. Acre	
1941	none	....	78	.....	0	0	5	5		98	
	2000	....	65	.....	1	1	21	30**		142	
1942	none	....	41	russet	....	....	....	....		144	
	2000	....	35	intermediate	....	....	....	....		198	
	4000	....	34	bright	....	....	....	....		192	
1943	none	6.2±0.1	68	russet	1	2	8	11		145	
	500	6.0±0.2	63	russet	2	3	14	24*	**	167	*
	1000	5.5±0.2	67	russet	4	7	13	22		162	
	2000	4.9±0.1	59	intermediate	12	21	22	38**		177	
1944	none	7.2±0.7	56	russet	7	12	28	48		172	
	2000	6.1±1.1	45	intermediate	15	33	48	106**		220	
1948	none	6.7±0.6	47	russet	1	4	60	215		352	
	2000	5.6±1.0	34	intermediate	6	24	91	364**		398	
	4000	4.5±1.2	31	bright	12	47	90	356**		394	
	6000	3.3±1.0	28	bright	16	64	84	336**		400	
1948	none	6.5±0.6	37	russet	1	4	87	366		422	
(sulfur	2000	5.5±0.5	32	intermediate	8	38	93	449**		474	
broadcast	4000	4.8±1.0	23	bright	31	151	98	476**		488	*
1947)	6000	3.9±0.3	20	bright	42	196	98	462**		467	
1949	none	6.4±0.4	38	russet	18	17	70	68		97	
(sulfur	2000	5.9±0.3	40	intermediate	15	20	70	93		133	
broadcast	4000	5.4±0.8	31	bright	40	49	82	101		123	
1947)	6000	4.9±0.1	27	bright	43	51	85	100		118	

[1] Unless otherwise indicated, sulfur was applied in the spring of the year of test.
[2] Soil reaction from the 3" to 4" depth in August.
[3] Yield of tubers graded over a 1⅞" screen.
* Yields significantly greater than the untreated plots at the 5 per cent level; ** at the 1 per cent level. Brackets apply to a comparison between the untreated control and the mean of the three sulfur treatments.

tubers with less than six per cent of the surface scabbed were significantly greater than those of the untreated plots. Total yields, relatively low because of the late planting date, were increased almost 50 bushels per acre, by 2000 pounds of broadcast sulfur. Since vines remained green until the end of the first week in October, yields were considerably higher than would normally have been expected.

Sulfur was broadcast on plots in April 1948 at rates of one, two, and three tons per acre. The soil reaction at the 3-4" depth with three tons of sulfur was reduced to pH 5.1 one month after application. After 75 days it had dropped to pH 3.8, and 100 days after application it reached pH 3.3. At the 6 to 8" level, in the plots receiving three tons of sulfur per acre, the soil

reaction was only pH 5.7 100 days after application. No differences in vine growth between plots were apparent. There was some burning of the tubers by sulfur at the three-ton rate and only a trace of injury with two tons. Chemical injury to the tubers resembled severe russeting of the tuber surface, and often a cheesy, crumbly type of rot was present below the skin.

In 1948, scab was considerably less severe than in previous years. Differences in yield between the untreated plots and sulfur treated plots were highly significant when tubers with less than six per cent of the surface scabbed were considered. Total yields, although not significantly increased, were slightly higher from the sulfur plots than from the untreated plots.

A marked difference was observed in the skin characteristics of the tubers from various treatments. Skins of tubers grown in soil receiving no sulfur were generally russeted and rather unattractive in appearance, whereas, those receiving two and three tons per acre had a smooth, white skin which was very attractive. The exact nature of the russeting was not determined, although it was probably russet scab.

In April 1947, sulfur was broadcast at rates of one, two, and three tons per acre. In the latter part of June, there were no discernible differences in vine growth of potatoes in any of the plots. These plots, lost because of flood early in July, were held fallow throughout the season and replanted in 1948. In 1947, the soil reaction (Fig. 2) in the upper 3-4" levels had been

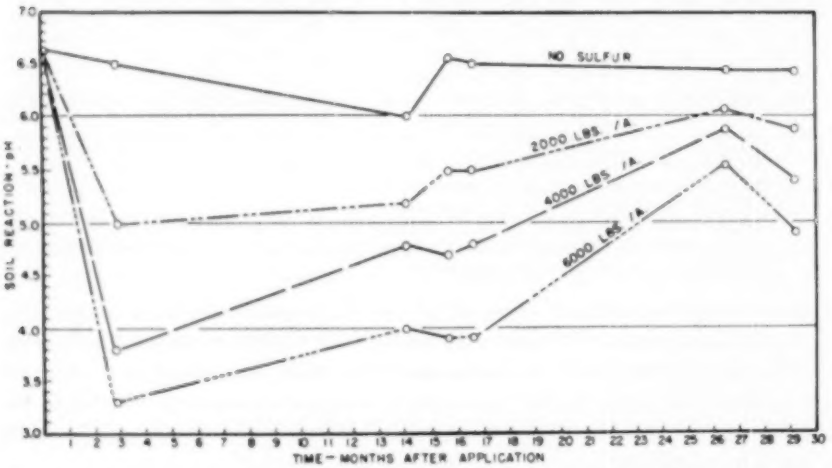

FIG. 2—Influence of broadcast sulfur on soil reaction at Crystal Lake, Iowa, 1947-1949.

reduced from pH 6.5 to 3.3 by 6000 pounds of sulfur within three months after application. Differences in soil reaction were apparent a year later and remained constant throughout that season. Scab control in the second year was good at each level of sulfur (Fig. 3 A, B, and C). In general, scab was

very light. Yields of tubers with less than six per cent of the surface scabbed in each of the sulfur treatments were significantly greater than those of the untreated plots. Total yields were increased significantly by sulfur applications when the three treatments were compared with no treatment. Tubers from the untreated plots were russeted and generally dull in appearance, whereas those from plots receiving 4000 and 6000 pounds of sulfur were bright and attractive. There was no sulfur injury to tubers the second year after soil treatment.

Potatoes were grown again in 1949 on the plots prepared in 1947. Although scab indices were slightly higher than in 1948, disease control was very satisfactory. Tuber skins remained bright at the two and three ton rate, whereas they were predominantly russeted in the one ton rate and in the untreated soil. Yields of scab free tubers and those with less than six per cent of the surface scabbed were considerably above those in the plots receiving no sulfur or the 2000 pound rate. Yields were not analyzed statistically because only a portion of each plot could be planted and pocket gopher damage made evaluation of differences difficult. Overall yields were low because these plants had not been sprayed with either fungicides or insecticides.

In all these trials, average total yields were consistently increased where sulfur was broadcast. In 1943 and 1948 total yields of the combined sulfur treatments were significantly greater than were those of the untreated plots. In other trials, total yield differences within a single experiment were not significant. However, when in all tests the 2000-pound rate was compared to the checks, total yield differences were highly significant. Yield increases were not visibly associated with increased plant vigor, better plant color, or any vine characteristic which could be identified.

In 1949 sulfur was broadcast on a peat bed at the south edge of Clear Lake. The reaction of untreated soil (Table 2) was slightly below pH 6.0 most of the season. Sulfur applications of 1000 pounds reduced the reaction to pH 5.0 by August and 2000 and 4000 pounds effected a still greater reduction. The one and two ton applications reduced scab indices appreciably. Tubers from plots receiving one and two tons of sulfur per acre had a bright white skin free of russeting and relatively free from deep scab, whereas tubers from the 1000 pound rate and the untreated plots were heavily russeted and severely scabbed. Yields of tubers with less than six per cent of the surface scabbed from 2000 and 4000 pounds sulfur rates were significantly greater than those from the untreated plots. In contrast to the results at Crystal Lake, sulfur applications did not significantly increase total yields although there was a slight overall increase with sulfur. In July, vines in the checks tended to be somewhat yellowish green, whereas in plots receiving sulfur they were more definitely a bluish green color. This characteristic became less conspicuous toward the end of the season.

a
b

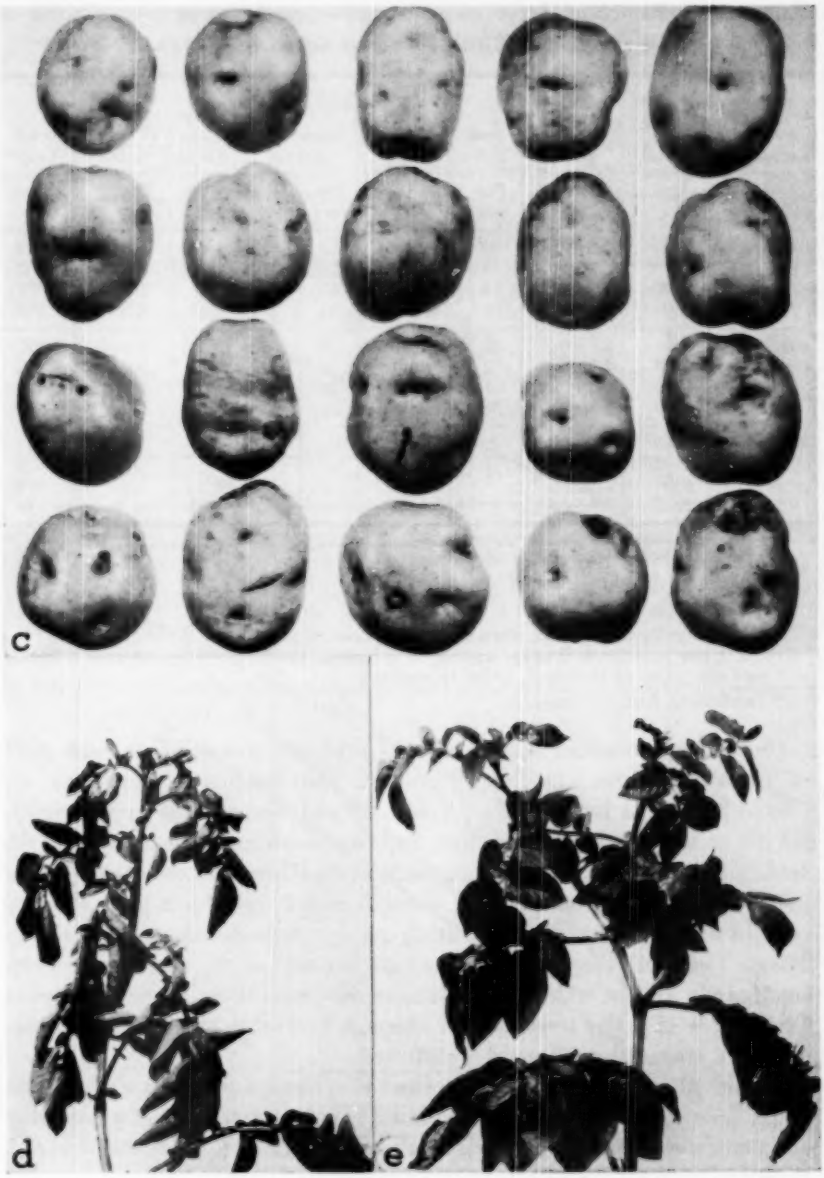

FIG. 3—Representative tubers from plots on peat at Crystal Lake two years after broadcasting sulfur. A, no treatment; B, 4000 pounds per acre; C, 6000 pounds per acre. Portions of Katahdin vines grown at Clear Lake in 1949: D, no treatment; E, 500 pounds of sulfur worked into the furrow.

TABLE 2—*Influence of sulfur on soil reaction, scab incidence, and yield of Cobbler potatoes at Clear Lake and Armstrong, Iowa, 1949.*

Location	Sulfur[1]	Soil Reaction[2]	Scab Index	Tuber Skin Appearance	Scab-Free Tubers		Tubers with Less Than 6 Per cent Surface Scabbed		Total Yield[3]
	Lbs. Acre	pH	Per cent		Per cent	Bus. Acre	Per cent	Bus. Acre	Bus. Acre
Clear Lake (peat)	none	5.6±0.2	39	russet	15	52	67	236	349
	1000	5.0±0.4	34	interm.	21	76	77	282*	363
	2000	4.2±0.2	24	bright	43	154	87	310**	357
	4000	3.6±0.1	18	bright	53	190	91	325**	358
Armstrong (raw peat)	none	5.1±0.2	35	bright	21	87	73	302	415
	500	4.9±0.1	32	bright	24	111	79	363 } *	462
	1000	4.6±0.2	28	bright	36	153	82	349 } *	424
	2000	4.3±0.3	26	bright	35	152	87	377 } *	433
Armstrong (burned peat)	none	8.3±0.1	†	bright	....	....	....	....	531
	500	8.0±0.3	†	bright	....	....	....	....	508
	1000	7.5±0.1	†	bright	....	....	....	....	499
	2000	7.3±0.1	†	bright	....	....	....	....	549

[1] Sulfur applied in the spring of 1949.

[2] Soil reaction from the 3 to 4" depth.

[3] Yield of tubers graded over a 1⅞" screen.

* Yields significantly greater than from the untreated plots at the 5 per cent level; ** at the 1 per cent level. Bracket applies to a comparison between the untreated control and the mean of the three sulfur treatments.

† Insufficient scab for readings.

Sulfur was broadcast on a moderately acid, raw peat soil four miles north of Armstrong, Iowa, in Emmet County. The reaction of untreated soil (Table 2) ranged between pH 5.5 and 5.0 and was reduced approximately 0.3 pH units by each level of sulfur. Scab was considerably less severe in this field in 1949 than it had been in previous years. There was no russet scab and lesions were deep, predominantly of the 3 and 4 type. Each level of sulfur reduced disease indices and moderately increased the percentage of scab free tubers. Yields of tubers with less than six per cent of the area scabbed were significantly greater with sulfur treatment than were those of the check plots. Total yields of sulfur treated plots, although somewhat higher, were not significantly greater than those of the checks.

In the same year, sulfur was applied to a burned peat bed situated one-fourth mile south of the above mentioned raw peat area. The effect of sulfur on potato yields in the absence of scab was determined, since this area was known to produce scab-free potatoes. The soil was rather alkaline in reaction, pH 8.3, and was reduced to pH 7.3 by the addition of 2000 pounds of sulfur (Table 2). Since scab was extremely light, disease records were not made. Sulfur applications up to one ton per acre apparently did not affect total yields.

Scab indices were plotted against soil reaction (Fig. 4) from data obtained over a four-year period on the sulfur plots at Crystal Lake, and for one year

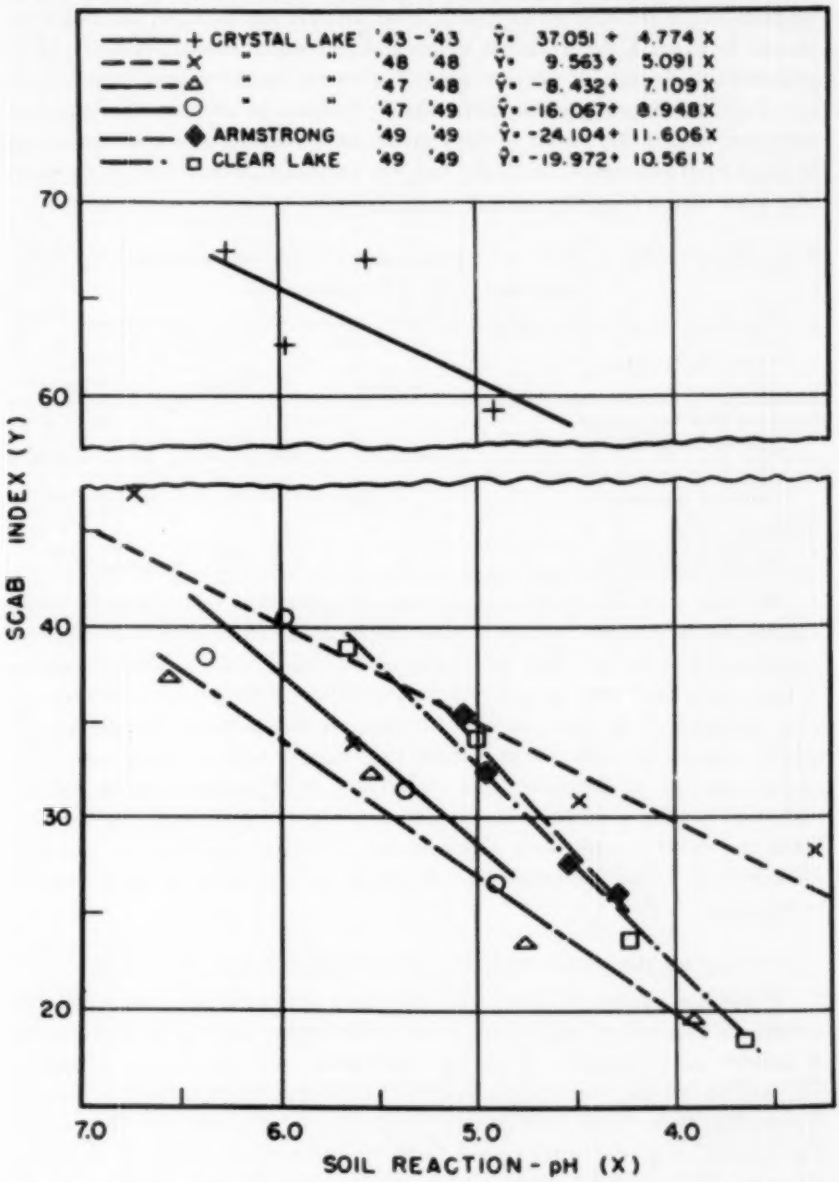

FIG. 4—Influence of soil reaction in August on scab incidence in three peat soils in northern Iowa. Regression equations were calculated from treatment means.

in each of two other locations. A co-variance analysis was carried out for each field experiment. As a result of this study, it was concluded that a reliable estimate of the relation between scab index and pH was given by the treatment means. In figure 4, the treatment means and regression lines are plotted and regression equations, ($\hat{y}$), are presented. There were no differences between relative slopes of these regression lines which could not be attributed to sampling variation (Table 3). In all of these trials, scab indices were reduced as the hydrogen-ion concentration of the soil was increased. There was no evidence of a toxic action of sulfur distinct from that of its influence on soil acidity.

TABLE 3—*Analysis of the errors of estimate from average treatment regression estimated from six experiments.*

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares
Deviation from the average treatment regression	17	651.16	.....
Deviation from the individual treatment regressions	12	366.37	30.53
Difference among treatment regressions	5	284.79	56.96

In 1943, scab indices were considerably higher than in subsequent years. This probably was due in part to seasonal variation and also to variation between readers since in 1943 the junior author made these readings whereas in later years they were made by the senior author. Precautions were taken to hold variation of the latter type at a minimum. Furthermore, the amount of sulfur required to bring about a given reduction in soil pH levels varied between locations. At Armstrong and Clear Lake, 2000 pounds of sulfur effected essentially similar reductions in soil pH levels whereas at Crystal Lake between 4000 and 6000 pounds were required for a similar reduction in soil pH. Despite these differences there were no significant differences in the regression coefficients.

CHEMICALS MIXED INTO THE OPEN FURROW BEFORE PLANTING

In 1945, a number of chemicals were tested at Crystal Lake in an effort to screen out those which might have promise for further investigation (Table 4). A number of ammonium-containing compounds were tested since Afanasiev (2) had shown that ammonium was toxic to *Streptomyces scabies* in culture. Ammonium thiocyanate provided good protection but yields were so low that the material was not investigated further. Ammonium carbonate and ammonium nitrate failed to reduce scab, whereas aluminum-ammonium sulfate was partially effective. Alfalfa hay and cow manure appreciably increased the

amount of scab and hydrated lime had no influence. Ammonium sulfate and sulfur appeared to be the most promising materials tested.

In 1946 at Crystal Lake, sulfur and ammonium sulfate were thoroughly mixed into the open furrow in one row plots replicated four times. Scab con-

TABLE 4—*Influence of soil amendments worked into the furrow on scab incidence and yield of Cobbler potatoes at Crystal Lake, Iowa, 1945.*

Amendment	Rate of Application	Scab Index	Tubers with Less Than 6 Per cent Surface Scabbed	Total Yield
	Lbs./A.	Per cent	Per cent	Bus./A.
None	.....	44	11	218
Sulfur	4000	36	26	242
Na_2SO_4	1000	47	13	250
$Al_2(SO_4)_3$, $(NH_4)_2SO_4$	1500	40	17	371
$(NH_4)_2SO_4$	500	35	38	274
$(NH_4)_2SO_4$	1000	35	33	355
NH_4NO_3	500	38	15	291
$(NH_4)_2CO_3$	1000	45	11	339
NH_4SCN	1000	31	46	89
Calcium cyanamide	250	46	16	250
Hydrated lime	2000	46	11	266
$CuSO_4$	50	46	9	307
$MnSO_4$	50	46	9	404
$ZnSO_4$	75	44	15	379
H_3BO_3	75	46	13	282
NaCl	1000	43	18	274
0-0-60	500	40	14	258
0-0-60	1000	42	15	266
0-20-0	1000	42	21	291
0-9-27	500	46	9	307
0-9-27	2000	38	25	339
Alfalfa hay		48	6	355
Grass hay		43	17	339
Cow manure		51	3	250

trol (Table 5) with 500 and 1000 pounds of sulfur per acre was good and injury caused by sulfur was slight. At the 2000 and 4000-pound sulfur levels chemical injury was severe. Total yields with certain rates of sulfur were significantly greater than those of untreated rows. Ammonium sulfate at 500

TABLE 5—*Influence of soil amendments worked into the furrow before planting on Cobbler scab incidence and yield.*[1]

Amendment and Rate of Application		1946				1948			1949		
		Soil Reaction	Chemical Injury	Tubers with Less Than 6 Per cent Surface Scabbed	Total Yield	Soil Reaction	Chemical Injury	Tubers with Less Than 6 Per cent Surface Scabbed	Total Yield	Tubers with Less Than 6 Per cent Surface Scabbed	Total Yield
	Lbs./A.	pH	Per cent	Per cent	Bus./A.	pH	Per cent	Per cent	Bus./A.	Per cent	Bus./A.
None		6.6	0	39	283	6.6	0	55	428	78	224
Sulfur	125									75	303
Sulfur	250									91	340
Sulfur	500	4.9	2.0	62	400	5.0	2	81	445	84	322
Sulfur	1000	4.3	11.0	65	356	4.6	8	70	450	90	261
Sulfur	1500									91	345
Sulfur	2000	3.9	28	59	271	3.4	11	67	300	91	290
Sulfur	4000	3.0	35	53	235	2.0	14	63	196		
$(NH_4)_2SO_4$	125					6.2	1	50	448	76	272
$(NH_4)_2SO_4$	250					6.1	1	58	501	82	275
$(NH_4)_2SO_4$	500	5.6	1	69	366	5.7	2	67	463	87	336
$(NH_4)_2SO_4$	1000	5.1	5	69	339	5.7	1	71	457	86	407
$(NH_4)_2SO_4$	1500									91	397
$Al_2(SO_4)_3$	125					6.6	0	49	426		
$Al_2(SO_4)_3$	250					6.5	0	56	472		
$Al_2(SO_4)_3$	500					6.5	1	69	443		
$Al_2(SO_4)_3$	1000					6.0	4	67	476		
M.S.D.	6 Per cent				50				74		97
M.S.D.	1 Per cent				69				99		130

[1] Yield of tubers graded over a 1⅞″ screen.

pounds per acre controlled scab equally as well as sulfur and chemical injury was only slight. Differences in yield between ammonium sulfate and sulfur at the 500-pound level were not significant. The soil reaction was slightly lower with 500 pounds of sulfur than it was with an equal amount of ammonium sulfate.

Trials in 1947 were lost because of flood.

Tests in 1948 were similar to those prepared in 1946. Aluminum sulfate was also included. Sulfur effected marked reduction in soil reaction at the 2-inch depth, and even greater reductions at the 4-inch depth. Chemical injury with the high applications of sulfur was considerable. The 500-pound rate appeared to be optimum for scab control, and for avoiding tuber injury. The greatest percentage of tubers with less than six per cent of the surface scabbed was obtained at the 500-pound rate. Total yields were higher than from the untreated rows, but the differences were not significant. Rather extensive observations were made on Cobbler stems in duplicate rows of the 0, 500, and 1000-pound rates of sulfur. At no time during the season were differences noted in the extent of scab lesions or of *Rhizoctonia solani* cankers on the stems. Yield reductions at the one and two-ton levels were significant. The optimum level for ammonium sulfate was somewhere between 500 and 1000 pounds per acre. Differences in yield were only slight at these levels. Greatest yields were obtained with ammonium sulfate at 250 pounds per acre, but there was no scab control at this rate. Aluminum sulfate had little effect on soil reaction, and if anything seemed to increase the amount of scab.

This test was repeated in 1949 at Clear Lake with essentially similar results. Scab control was very satisfactory when sulfur was thoroughly mixed into the open furrow before planting. Formaldehyde sprinkled into the furrow before planting (1 per cent formaldehyde at 290 and 580 gallons per acre) was not effective in reducing scab and yields were somewhat impaired.

Sulfur was applied in bands below the seed using the fertilizer attachment of the potato planter in 1948 and 1949. No yield differences were obtained and scab was not reduced by this treatment.

Varietal Response to Sulfur in the Furrow

In 1948, at Crystal Lake, 18 varieties of potato were tested in a split plot design in which sulfur at 500 pounds per acre in the furrow was compared to a control (Table 6). Wherever possible, four replications were prepared, but in certain instances seed supply was not sufficient. It was possible with some varieties to test seed from different locations. Yield responses to sulfur were significant in an analysis of variance and no interaction was obtained between treatment and varieties. In general, yields were decidedly increased by 500 pounds of sulfur, although with two varieties, Red McClure and Chippewa, a reversal was obtained. Seed source had little to no effect upon the response.

TABLE 6—*Influence of sulfur in the furrow on yield of potato varieties from a number of sources at Crystal Lake and Clear Lake, Iowa.*

Variety	Area in Which Seed Was Grown in 1947	Total Yield					
		Crystal Lake—1948			Clear Lake—1949[1]		
		Sulfur Bus./A.	No Sulfur Bus./A.	Increase Bus./A.	Sulfur Bus./A.	No Sulfur Bus./A.	Increase Bus./A.
Cobbler	Crystal Lake, Ia.	472	451	21	546	492	54
	Hancock, Wis.	429	363	66	458	374	84*
	Armstrong, Ia.	568	487	81*			
Pawnee	Crystal Lake, Ia.	310	214	97*	508	326	182**
	Hancock, Wis.	378	311	67			
Katahdin	Crystal Lake, Ia.	390	372	18	786	508	278**
	Hancock, Wis.	399	372	27			
Red Warba	Crystal Lake, Ia.	381	354	27	516	304	212**
	Hancock, Wis.	472	369	103**			
	Albert Lea, Minn.	447	417	30			
Triumph	Crystal Lake, Ia.	224	172	51	368	250	118**
	Hancock, Wis.	251	191	60			
	Three Lakes, Wis.	332	236	96*			
Pontiac	Crystal Lake, Ia.	429	387	42			
	Hancock, Wis.	520	463	57			
Red McClure	Hancock, Wis.	208	217	(—9)	210	158	52
Chippewa	Crystal Lake, Ia.	315	290	24	554	570	(—16)
	Hancock, Wis.	378	399	(—21)			
Gr'n Mountain	Webb, Ia.	420	383	37			
LaSalle	Crystal Lake, Ia.	523	490	33			
White Rose	Hancock, Wis.	287	239	48			
Sebago	Crystal Lake, Ia.	391	371	20	476	438	38
	Hancock, Wis.	471	466	5			
	Armstrong, Ia.	402	381	21			
Ontario	Hancock, Wis.	338	310	28	342	323	19
	Three Lakes, Wis.	347	303	44			
Menominee	Crystal Lake, Ia.	211	157	54	388	369	19
	Hancock, Wis.	272	224	48			
116-13	Crystal Lake, Ia.	411	317	94*	474	351	123**
Cayuga	Crystal Lake, Ia.	266	200	66			
Russet Rural	Three Lakes, Wis.	414	363	51	412	379	33
Russet Burbank	Three Lakes, Wis.	296	212	84*	231	132	99*
	Albert Lea, Minn.	311	239	72			
Yampa					277	280	(—3)
6316					361	285	76

[1] All seed grown at Crystal Lake, Iowa, in 1948.

* Significant yield increase at the 5 per cent level; ** at the 1 per cent level.

The reduction of scab on Cobbler in 1948 (Table 5) in a similar test is indicative of the extent of disease control obtained on susceptible varieties.

In 1949, similar plots were prepared on a peat of similar type at Clear Lake, Iowa. Fifteen varieties, the seed of which had been grown at Crystal Lake the previous year, were tested in a split plot design with four replications. Scab incidence on Cobbler was determined in another trial in which sulfur had been applied in a similar manner (Table 5). Yield responses were marked, particularly with certain varieties. In this analysis, there was a significant variety-treatment interaction. In 1948, not all seed sources of a given variety responded to the same extent. However, at least one seed lot of Cobbler, Pawnee, Red Warba, Triumph, Russet Burbank, and 116-13 responded significantly to sulfur. In 1949, these same varieties responded significantly to similar sulfur treatments at another location. The only exception was Katahdin, which responded slightly at Crystal Lake and showed a large yield increase at Clear Lake. Chippewa was the only variety which was influenced adversely at both locations by sulfur, although Red McClure and Yampa showed some reduction in yield. Most of the varieties responding by yield increase were susceptible to scab; however, in these plots Russet Burbank and 116-13 were resistant.

Differences in vine type, especially with certain varieties, were evident in 1948 and were more clearly shown again in 1949. In general, where a response was noticed, plants in the untreated rows were slightly chlorotic, or at least a yellowish-green color, often slightly reduced in size, and characterized by a marked upward rolling of the leaflets (Fig. 3 D and E), whereas, plants in the sulfur-treated rows were a darker green, more vigorous, and exhibited a marked reduction in this leafroll type of symptom. Differences of this type were most pronounced in the middle or later portion of the season. Although virus leafroll may have been present in some of the plants, it is doubtful that the difference in symptom was due entirely to an effect on expression of the virus leafroll disease. Rather it is suspected that the response was caused by differences in nutrition as influenced by the presence of sulfur in the soil. In general, varieties exhibiting marked differences in leafroll following sulfur treatment likewise responded by the most pronounced increases in yield.

Influence of Sulfur on Quality and Flavor[3]

During the course of the work attention was given to the influence of sulfur on the quality and flavor of potatoes. The specific gravity of potatoes was not influenced by rates of sulfur up to 6000 pounds per acre. Analyses of sulfur, iron, and manganese were made and no differences were obtained between the control and the 6000-pound level of broadcast sulfur. The percentage of these elements on a dry weight basis ranged from 0.115 to 0.202 with sulfur, 0.0008 to 0.0029 with iron, and 0.07 to 0.17 with manganese. Tests on flavor

in 1946 were made in cooperation with the Home Economics Section. No differences in flavor, aroma, and mealiness were observed. In 1948 and 1949 samples were given to more than 40 individuals and again no consistent differences in the above mentioned qualities could be detected.

Discussion

The use of sulfur in reducing the severity of potato scab on peat soils in Iowa is of limited practicability, at least in certain areas, because of the high cost for effective rates of sulfur. Sufficient quantities of sulfur decidedly reduced the incidence of deep and russet scab, although in none of these soils was scab eliminated. Since profitable potato production is impossible on some of these peats when susceptible varieties are grown, sulfur promises to be of value as a soil conditioning agent.

Considerable evidence has been presented elsewhere indicating that as the hydrogen-ion concentration of the soil is increased, scab incidence is reduced. In these studies on peat soils, scab indices were reduced as pH levels were reduced following sulfur treatments. It is realized that observations were limited to certain peat soils in northern Iowa and that only the Cobbler variety was used. However, there were no significant differences in the slopes of regression lines made from data from different seasons, or from different locations.

There was no evidence that sulfur had been deleterious to potato yields. In no case were yields reduced by broadcast applications and in certain locations sulfur in appropriate rates actually increased yields. The effect of sulfur on yields of potatoes as reported by others has been variable. Sulfur in heavy rates on certain mineral soils has been reported to reduce yields and plant vigor. In general, yield increases have not been great, although in certain trials stimulation has been reported. Rather striking results have been obtained with potatoes and other crops in France on mineral soils (9, 11) and on calcareous clay soils (7).

Sherbakoff (41) obtained rather consistent yield increases the first season after broadcast applications of sulfur ranging from 300 to 900 pounds per acre in two extensive field trials. The second season yields were more or less reduced by 450 to 900 pounds of sulfur. Martin (34) obtained rather marked total yield increases using sulfur in one experiment where the soil reaction was only slightly changed, and a slight yield decrease in another trial where a low soil reaction, pH 4.7, was obtained. He later (35) reported a very slight reduction in potato yields in Sassafras loam at pH 4.2 to 4.8 following soil treatment with inoculated sulfur. Wessels (43) obtained good yields in soil reactions of approximately pH 5.0 and higher. Muncie

[3] The authors are indebted to Dr. C. E. Peterson of the Horticulture Section; Dr. J. A. Wilkinson of the Department of Chemistry; and Dr. Belle H. Lowe of the Home Economics Section, for cooperation in making these determinations.

et al (36) obtained increases in total yield in two out of four years in plots where sulfur had been plowed under or disked into the soil. In these years, the soil reaction of the sulfur treated plots with one exception was pH 4.8 or lower.

Yield increases resulting from sulfur applications have been reported elsewhere, but the underlying reason for such increases has been attributed to a number of factors. In Iowa (8) yield increases of alfalfa and to some extent of oats and clover have resulted from applications of gypsum or sulfur. The effect of gypsum was believed to be that of a sulfur fertilizer. Powers (38) obtained increased yields with a number of crops following the addition of sulfur to Oregon soils and considered that sulfur was a limiting element on these soils. He obtained marked increases of potato yields in loam soil in one location, moderate yields in another and no response in a third location. Increased yields of potatoes were attributed to scab control as well as increased ammonification in sulfur-treated soils. He reported that yield responses of other crops to sulfur were generally poor in peat and muck soils.

There is a possibility that the influence of sulfur on yields may be due at least in part to additional nutritional factors. Yield increases following soil treatments with sulfur have been attributed to the indirect effect of sulfur in increasing the availability of phosphorus (31, 38). Ligon (30) observed increased solubility of phosphorus, potassium, and calcium in sulfur-treated muck soils whereas nitrification was frequently decreased. Others (10) observed increases in NH_3 in soil within ten days following treatment with sulfur. Joret and Malterre (26) reported rather consistent yield increases of potatoes in calcareous, alluvial soils following sulfur treatment. In August the nitrogen content of both tubers and tops was higher in the sulfur treated plots than in the controls. Fife (19) had previously observed that ammonification and nitrification was increased by additions of sulfur to Utah soils and Greaves and Gardner (22) reported that sulfur-carrying salts increased the nitrogen fixation of certain Utah soils.

More recently Harmer (23) and MacLachlan (33) have reported yield increases on peat and muck soils following additions of sulfur. These investigators attribute yield increases to the indirect influence of sulfur increasing the availability of manganese. Cooperative investigations with the Horticulture Section of this station, the results of which are not ready for publication, have indicated at least a partial manganese deficiency on peat soils at Clear Lake, Iowa.

An indication of variation in the response of potato varieties to sulfur treatment was made by Von Feilitzen (17) in which he reported that yields of Harbinger, Jemtlans, and Magnum Bonum were increased, those of Jubel were reduced, and those of Flour Ball were unaffected by sulfur treatments. Jubel was the only scab resistant variety tested. There was no consistent influ-

ence on starch content in these tests. In the Iowa tests, most varieties responded to sulfur treatment, although some responded more consistently than others. The response to sulfur was apparently not influenced by scab resistance or susceptibility. Sulfur reduced yields of Chippewa, a scab-susceptible variety, whereas, it increased yields of most other varieties whether scab-resistant or susceptible.

In these trials, leaves of plants treated with sulfur in the furrow were generally a darker bluish-green color suggesting high nitrogen nutrition whereas the plants from untreated plots were often a lighter green color and exhibited a leafroll symptom somewhat like that of incipient nitrogen deficiency (25), although appearing to be more similar to that of virus leafroll. Jones' and Brown's description (25) of phosphorus deficiency fits somewhat the symptoms observed in so far as leafroll is concerned. However, the color of phosphorus-deficient plants is reported to be darker than normal, whereas in these tests the untreated plants were a paler green color. Crocker (14) reported that foliage of plants deficient in sulfur was a pale green or yellow color. Unfortunately he does not describe symptoms on potato. Descriptions of acute manganese deficiency on potato are available, but in so far as the authors are aware, partial manganese deficiency symptoms have not been described. Harmer and Sherman (24) report better color and a deeper shade of green in potatoes in which a partial manganese deficiency was corrected by spraying. Bernhard (4) reported that yields were higher and that the leafroll disease of potatoes was less prominent on sulfur-treated plots than in the controls. Slight masking of primary leafroll symptoms by high nitrogen nutrition has been reported by Rigot (40). Richards *et al* (39) observed masking of leafroll in the Green Mountain variety when nitrogen fertilizers were used in the greenhouse during the winter, but observed no masking during the summer in the field. Felton (18) observed masking of leafroll in infected Triumph plants at 80° F. in both dry soil and in quartz sand culture containing an abundance of nitrogen. With low nitrogen nutrition, virus leafroll was exaggerated, whereas non-virus plants exhibited a folding and cupping of the leaves. In the Iowa tests the sulfur-treated plants in which the leafroll symptom was not apparent showed evidence of high nitrogen nutrition whereas plants receiving no sulfur appeared to be somewhat deficient. LeClerg (29) observed non-virus leafroll in seedling progenies and certain named varieties. Although symptoms were very similar to virus leafroll, leaves of affected plants were not quite so brittle as those infected with virus leafroll and the yields were normal. Varieties listed in order of decreasing expression of non-virus leafroll were Chippewa, Katahdin, Sebago, Triumph, Cobbler, Red Warba, Green Mountain, and Pontiac. He did not report masking of this disorder in his tests, although he suggested that symptom expression is influenced by environmental conditions. One characteristic contrasting with virus leafroll was the uniformity of symptom expres-

sion where non-virus leafroll was present. In the Iowa tests, where the symptom was evident, most plants were uniformly affected, and when it was not evident, plants appeared to be uniformly healthy. Furthermore, yield reductions were not so great as should have been expected were virus leafroll present in all plants. When these seed lots were indexed in the greenhouse, leafroll symptoms were not obtained. It is doubtful if masking of virus leafroll is the entire problem in Iowa, since in field observations over a period of years considerable leafrolling has been observed in stocks of seed known to be free from this virus. It is probable that the leafroll symptom observed may have been influenced by partial deficiencies or excesses of other minerals.

Although the hydrogen-ion concentrations in certain sulfur-treated Iowa peat soils are rather high, it should be pointed out that the depth to which the soil was treated did not exceed four to five inches the first year after broadcasting and probably did not extend over six to eight inches in subsequent years. Thus, many of the potato roots were in the deeper soil layers which were relatively unaffected by sulfur applications. Smith (42) observed relatively poor growth of potatoes, characterized by off-yellow color and early maturity, in mineral soil at pH 4.7, whereas yields were optimum at pH 5.5. Adams (1) reported some variation in growth of clover and alfalfa in acid soils of different types. In a sandy soil, growth was very poor at pH 4.1, whereas in a silt loam growth was good at pH 3.5. Apparently the peat soils studied, particularly the one at Crystal Lake, had a considerable hydroxyl-ion reserve requiring over two tons of sulfur per acre. Sulfur rates reported by other investigators on mineral soils seldom exceed 2000 pounds per acre. There was no indication, judging from yields and vine characteristics, that peat soils too acid for potatoes had been developed.

Summary

A number of compounds were tested as soil treatments to prevent scab of potatoes on calcareous peat soils in northern Iowa. Of the group, sulfur and ammonium sulfate were the most effective.

At Crystal Lake, 4000 pounds of sulfur per acre was required for commercial control, whereas at Clear Lake, 2000 pounds was effective. Marked reduction in russet scab as well as deep scab was obtained at both locations.

As the hydrogen-ion concentration of these soils was increased, scab indices were reduced. Although the amount of sulfur required to effect a given change in soil reaction varied in the different locations, there were no real differences in the relative slopes of the regression lines from field trials at different locations and different seasons.

There was no indication that *Streptomyces scabies* had become adapted to acid soil conditions at Crystal Lake during a three-year period.

For equal control, sulfur worked into the furrow was required in smaller

amounts than in broadcast application. Effectiveness of furrow application depended upon the thoroughness with which sulfur was mixed with the soil. The usefulness of this method is limited by the lack of suitable machinery for application.

Ammonium sulfate when applied in the furrow was approximately equal to sulfur in controlling scab. Aluminum sulfate failed to control scab and, if anything, seemed to increase scabbiness.

Sulfur applied in bands using the fertilizer attachment on the planter was not effective in reducing scab.

Chemical injury to tubers resulted from excessive applications, and also when sulfur was insufficiently mixed with the soil. It consisted of a russeting of the tuber surface and, in severe cases, of a crumbly, cheesy rot of the underlying tissues.

Yields of Cobbler potatoes at Crystal Lake were increased from 40 to 50 bushels per acre by broadcast applications of one or more tons of sulfur per acre.

Certain varieties responded more than others by increased yields following treatment with 500 pounds of sulfur per acre worked into the furrow. Most varieties yielded better with sulfur than without it. Greatest responses were obtained with Cobbler, Pawnee, Red Warba, Triumph, Katahdin, scab-susceptible varieties, and Russet Burbank and 116-13, scab resistant varieties. Yields of Chippewa, a scab susceptible variety, were reduced.

A leafroll symptom present in many seed lots was alleviated, at least in part, by sulfur applied in the furrow.

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FEEDING EFFECTS OF *EMPOASCA FABAE* ON A RESISTANT AND SUSCEPTIBLE VARIETY OF POTATO[1,2]

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(Accepted for publication May 12, 1950)

Observations on populations of *Empoasca fabae* (Harris) and yields of resistant and susceptible varieties of potatoes revealed that the relatively resistant Sequoia variety had nearly as high leafhopper populations and nearly as great yield reductions because of leafhopper injury as the susceptible Irish Cobbler variety, under Minnesota conditions. On the Cobbler variety the development of hopperburn was the most conspicuous symptom; however, stunting and curling of leaflets and dwarfing of plants also occurred. The development of severe infestations of leafhoppers was soon followed by death of the vines. The tolerance of Sequoia was quite remarkable considering its moderately high leafhopper populations. Although stunting and curling of leaflets as well as dwarfing of plants were evident, very little hopperburn developed, and the plants remained green until frost.

Histological studies of *Empoasca fabae* feeding injury on leaves of the Cobbler and Sequoia varieties were undertaken in an effort to observe cellular changes associated with the development of hopperburn and to discover possible explanations for the great difference in tolerance of these varieties to leafhopper injury.

METHODS AND PROCEDURE

Comparisons of leafhopper feeding injury on the Cobbler and Sequoia varieties were based on four series of sections. The first series of sections was prepared from leaflets of healthy plants of each variety grown in the greenhouse. The second series, made from leaflets of field plants dusted periodically with DDT, was intended to substantiate results of the first series. The third series was prepared to show early feeding injury by *Empoasca fabae*, and a single late-instar nymph was confined for a five-day period on a single leaflet of each variety in the greenhouse. The fourth series was made from leafhopper-infested leaflets of plants in undusted field plots to demonstrate later stages of feeding injury.

Similar portions of leaflets of each variety were selected from approximately the same height on each plant and fixed in formalin-acetic-alcohol. The material was subjected to a common method of dehydration in normal butyl

[1] Paper No. 2559, Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul 1, Minnesota.

[2] This material was included in a thesis presented by the senior author to the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the Ph. D. degree.

alcohol, embedded in *Tissuemat*[3], sectioned at a thickness of 10 microns, and stained in safranin and fast green.

Varietal Differences in Normal Leaflets

Some differences were apparent between the leaf veins of healthy Cobblers and Sequoias grown in the greenhouse. Veins of Sequoia leaflets were usually larger with sometimes greater development of the ridge on the midvein. Cortical cells were often more numerous and larger in size in Sequoia resulting in greater distance between lower epidermis and phloem; however, this difference was not always consistent. The vascular region of the midvein frequently occupied a noticeably greater area in Sequoia, and bundles of both external and internal phloem tended to be larger and more numerous than in Cobbler. Collenchyma cells were thicker-walled in Sequoia.

Sections from leaflets of DDT-dusted plants had thick leaves and smaller veins with a more compact arrangement of cells than in greenhouse-grown plants. As compared with Cobbler, Sequoia again had a slightly larger midvein, somewhat broader cortical area, more extensive phloem, and thicker-walled collenchyma.

Injury on Cobbler

As might be expected from results of Granovsky (1), Smith and Poos (4), Smith (3), and Medler (2), the early stages of feeding injury were characterized by the presence of a diffused sheath and injury to the phloem.

Slight to moderately severe injury was evident in sections of Cobbler leaflets which had been exposed to leafhoppers for a period of five days in the greenhouse. Among 67 feeding punctures studied in the Cobbler, the feeding injury was obvious through an average of 5.5 sections which is equivalent to a distance of 55 microns. Medler (2) obtained an average of 50 microns for extent of feeding injury to alfalfa which was sectioned after a three-day exposure to *E. fabae*. Injury to Cobbler was usually characterized by the presence of diffused sheath material, localized hypertrophy of phloem cells, and conspicuous enlargement of nucleoli of affected cells (Fig. 1). These symptoms are similar to those described by Medler (2). The outer, or abaxial, phloem was more frequently affected because it is nearer the under surface of the leaf where the leafhoppers habitually feed. Hypertrophy of phloem cells was followed by disorganization of the tissue (Figs. 1, 2). Inner, or adaxial, phloem usually became involved as the injury progressed. Occasionally there was evidence that the insect mouth parts may have penetrated the outer phloem and xylem to reach the inner phloem. Sometimes the phloem disorganization seemed to progress from the outer phloem around the xylem to the inner phloem. A conspicuous cell inclusion which stained heavily with safranin com-

[3] An embedding compound manufactured by Fisher Scientific Company, Pittsburgh, Pa.

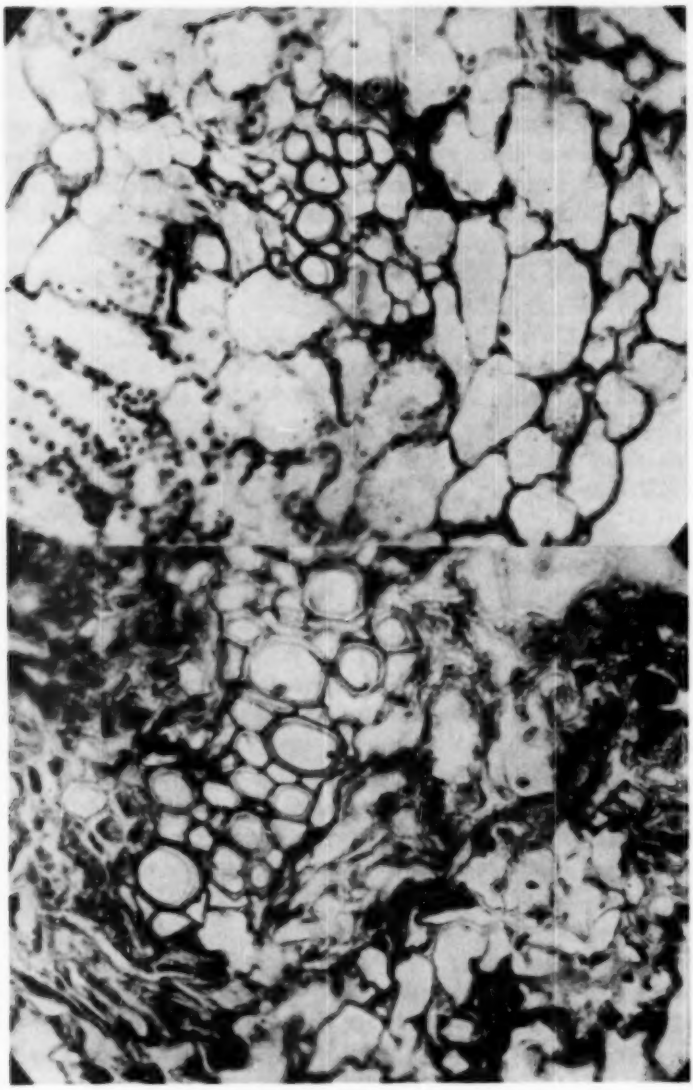

FIG. 1—(Upper) Lateral vein of Cobbler leaflet, 400X. Conspicuous sheath occurs in the outer phloem. Hypertrophy of cells and enlargement of nucleoli are evident. Disorganization of phloem is beginning.

FIG. 2—(Lower) Severe injury to midvein of Cobbler, 400X. Phloem is completely disorganized.

monly occurred in nearly every cell of the palisade layer and in many cells of the spongy layer. A similar small body occurred in each plastid of the palisade and spongy cells in the region of injured veins. Such cell inclusions were absent in healthy leaflets grown in the greenhouse and occurred only near the extreme lateral margins of leaflets from DDT plots.

Cobbler leaflets from undusted plots appeared thicker and turned yellow more rapidly in the fixing agent. (formalin-acetic-alcohol) than corresponding leaflets from DDT plots. Although hopperburn was not extensive on leaflets from undusted plots, the sections revealed severe leafhopper injury. The phloem was disorganized and consisted of lignified layers of cell remnants (Fig. 2.) Plastids were disintegrated and cells filled with starch grains and a granular material (Fig. 3). This type of injury was described by Granovsky (1). Severe plasmolysis of palisade cells was evident in regions adjacent to the injured veins (Fig. 3).

Injury on Sequoia

Early *E. fabae* injury to Sequoia was similar to that observed in Cobbler. Among 44 feeding punctures studied in the Sequoia, feeding injury was evident through an average of 5.0 sections which is equivalent to a distance of 50 microns. Although sheath material was frequently less conspicuous in Sequoia, the sheath was sometimes exceptionally well defined (Fig. 4). Hypertrophy was less severe and more localized in Sequoia, but nucleoli were just as much enlarged as in Cobbler (Fig. 4). Considerable injury was sometimes evident in Sequoia leaflets, and both outer and inner phloem disorganized. Conspicuous red-staining inclusions were present in cells of palisade and spongy layers of leafhopper-injured Sequoia leaflets as in Cobbler leaflets. The similar small bodies in the plastids near injured tissue were also evident. Injury in Sequoia was not found to proceed beyond this point. No plasmolysis of cells, disintegration of plastids, or development of granular material occurred in any of the sections observed.

Conclusions

Histological observations on Cobbler and Sequoia indicate that leafhopper feeding has a more severe effect on phloem and adjacent parenchyma in Cobbler; there is more break-down and disorganization of cells and greater masses of red-staining necrotic tissues. Severe plasmolysis and disintegration of plastids observed in late stages of injury in Cobbler were not found in Sequoia.

It appears that varietal differences in reaction to leafhopper feeding may involve both morphological and physiological characteristics. Thicker-walled collenchyma in Sequoia may have some effect on tolerance to leafhopper attack. More extensive phloem and its often greater distance from the lower epidermis in Sequoia may be of some importance in accounting for the less

FIG. 3—(Upper) Palisade cells near severely injured midvein of Cobbler, 900 X.

FIG. 4—(Lower) Lateral vein of Sequoia, 400X. A conspicuous sheath lies near center of picture.

prevalent injury to inner phloem. The less severe injury to inner phloem apparently results in less interference with translocation and somewhat smaller accumulations of carbohydrates in chlorophyll bearing tissues of Sequoia as compared with those of Cobbler.

It is believed that the conspicuous development of hopperburn in Cobbler and the lack of appreciable hopperburn in Sequoia, which occur despite nearly equal leafhopper populations, may be explained by several factors. Severe leafhopper injury was evident histologically in both varieties before visible symptoms of hopperburn appeared. Continued accumulation of sugars and polysaccharides seems to occur in Cobbler, and it is believed that excessive accumulations of these materials may eventually result in plasmolysis and death of the tissues and appearance of hopperburn. Apparently such high concentrations of carbohydrates do not develop in Sequoia. There is also some indication of a varietal difference in physiological response to the toxin injected by the leafhopper during the course of feeding.

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SECTIONAL NOTES

California

At the present time Kern County growers are harvesting the late crop of potatoes grown in the mountain areas both east and west of Bakersfield. It is estimated that there are approximately 3500 acres of fall potatoes in our county this year.

Part of this crop is being certified and held for seed to plant the 1951 spring crop. In general, the quality is good. However, some losses from heat necrosis have been sustained, due probably to the exceptionally high temperatures which prevailed during the latter part of the summer.

Estimates regarding the possible acreage to be planted next spring are impossible to make at the present time. However, it is certain that the cotton acreage allowed will be a great factor. In general, the more cotton acreage allowed, the less the acreage of potatoes that will be planted.—David N. Wright.

Indiana

It may be some time before we get a report in regard to the referendum concerning the potato deal in Indiana as the ballots were sealed and mailed on the 30th of September. As you know, we have no results to report other than this, that among our growers one hundred per cent of them are against the referendum, according to very reliable information handed to me this morning.

Indiana potatoes are moving quite well. The price is quite reasonable, and the quality is exceptionally good. The yields are good and the foliage, for the most part, on a lot of fields is still green. We have used some vine killer to mature the crop and in some of the low muck areas a frost also assisted. So far we have no report of any wasted potatoes being dumped in the field nor fed to livestock.—W. B. Ward.

Long Island

In sharp contrast with last year, the present Long Island potato crop is of excellent quality and yields are among the highest on record. This would make a very encouraging situation for the growers if the market demand and price were good, but potatoes are selling unusually slowly and the prices are very low.

All the Cobblers were harvested in August, and in September we started the harvesting of Katahdins, which is now one of the dominant varieties grown in this area. Growers prefer to market Katahdins directly after harvesting instead of storing them, but the sluggish market has forced us to put some Katahdins into storage. Green Mountains are now being dug, and most of the crop is going into storage at the present time (October 3). Pontiac was in great demand the latter part of September for the export market.

Many Long Island growers are trying small acreages of late-planted potatoes for a special storage crop. The regular crop is planted in late March and April and the late crop is planted in June or early July. In general, the potatoes which mature in late October and early November have superior storage quality compared with those which mature in August and September. Some farmers have experienced tough luck this fall with their late plantings, because of infestations of late blight, but the experiment of planting in June is still of considerable interest.—J. Howard Ellison.

Michigan

Harvesting is well under way on the late crop. The movement of the early area was slow and is, at present, practically cleaned up. This has made a slow start on the shipments of the late crop.

Our yields are high and the quality of table stock is good. Certified seed yields are higher than last year with tuber size also smaller than last year, which makes a much more desirable seed size.

All reports show that the Marketing Agreement in this area has passed. This area group consists of Michigan, Wisconsin, Minnesota, and North Dakota, with parts of Indiana and Iowa. The report just released indicates that 5,557 growers voted, of which 75.3 per cent were in favor of the program. By volume, 25,488,585 bags were represented in this vote, of which 72 per cent voted favorable. This amount consisted of the volume which was 65 per cent of the production.

There has been some movement on the support program to institutions. Also, a small amount has been dumped or used for livestock feed.

This Marketing Agreement program will have a tendency to induce growers to hold for support, as markets at present are below support.—H. A. REILEY.

NEBRASKA

At this time western Nebraska is in the middle of its potato harvesting period. The weather has not been too favorable to date because excessive moisture has saturated most fields. Light rains have also interrupted our harvesting operations a number of times. In some areas potatoes are carrying more dirt than usual as they go into storage.

Above average quality prevails in most dryland fields and average quality is general under irrigation. Our yields are better than average, with reports of 90 to 175 bushel yields from dryland and 300 to 600 bushel yields from irrigated fields.

With a very poor market at the present time, practically no potatoes have been sold to date. Nearly the entire crop will go into storage. It is apparent that most cellars will be filled to the doors with an overflow going into temporary storage pits on a number of farms.

A referendum recently conducted in the western Nebraska and eastern Wyoming area for a proposed Marketing Agreement resulted in 78 3 per cent disapproving, and 21.7 per cent approving. The rate covered approximately 51 per cent of the commercial potato producers of the area.—WARREN TRANK.

NEW YORK

As of October 2nd the late potato harvest is starting in earnest. After three weeks of poor harvesting weather we are having Indian Summer and our growers are now harvesting good quality crops.

Although our yields are not so high as last year, the quality is better in that the potatoes are more mature and will go into storage with less bruising. Blight has been reported in some unprotected fields but the efficient grower has a good crop.

New York State turned down Marketing Agreements and is marketing its own crop this year. With the fine quality and a fairly good demand it is expected that our crop will go to market without too much trouble. It is the com-

mon opinion of most potato men who ought to know, that there is not the crop the Government Estimate indicated.

Our acreage of certified seed will be down this year and consequently the yield. There is practically no seed demand as yet but when it comes we will have some excellent potatoes available.—H. J. Evans.

Province of Ontario

The quality of this year's Ontario potato crop is the best we have experienced for many years. There is a very noticeable decrease in the amount of scab, and blight has not caused the amount of loss anticipated a few weeks ago. There is also less damage from bruising. All tops are mature, and digging is now in progress. There is renewed interest in grading and packaging.

Our prices are unusually low. Potatoes continue to offer the best buy of all food commodities. Many growers are disappointed with their returns, and unless more satisfactory results are forthcoming, our acreage will be drastically reduced another year.—R. E. Goodin.

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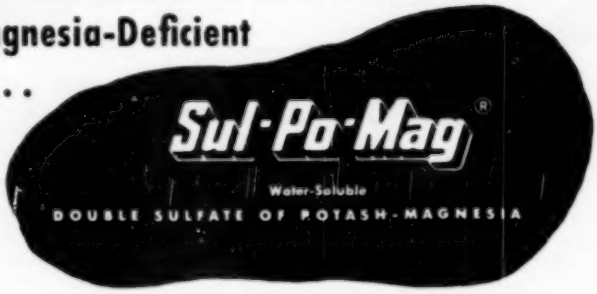

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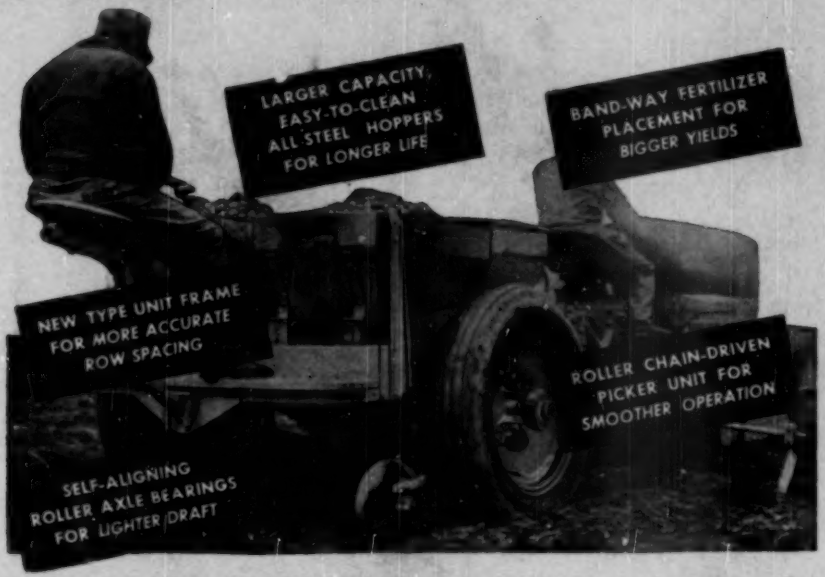
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